San Joaquin Renewables Class VI Permit Application Post-Injection Site Care Plan

Prepared for

San Joaquin Renewables LLC
McFarland, California

Submitted to

U.S. Environmental Protection Agency Region 9
San Francisco, California

Prepared by

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1. Introduction

This Post-Injection Site Care (PISC) and Site Closure Plan is a component of the San Joaquin Renewables, LLC (SJR) application to the U.S. Environmental Protection Agency Region 9 (U.S. EPA) for an Underground Injection Control (UIC) Class VI permit for a planned facility located in McFarland, California. This plan is one of eight separate documents submitted to the U.S. EPA Geologic Sequestration Data Tool (GSDT), and includes required information regarding planned post-injection monitoring activities and site closure. Numerical modeling used to define the areas of anticipated carbon dioxide migration and the Area of Review (AoR) are described in the Area of Review and Corrective Action Plan. Geologic analyses that underpin the conceptual model used in the AoR numerical modeling is primarily described in the narrative permit application report.

The permit application and associated documents were prepared by a team including Daniel B. Stephens & Associates, Inc. (DBS&A), Driltek, Finsterle Geoconsulting, Keystone Diversified Energy, Inc. (KDEI), and Best Core Services.

2. Pre- and Post-Injection Pressure Differential

Pressure within the injection zone (Vedder formation) is simulated to increase during the injection phase (15 years), and decline following injection. Modeling methodologies, sensitivity analyses and detailed results are included in the AoR and Corrective Action Plan. Figure 1 displays simulated pressure at the location of the injection well. Initial pressure (prior to injection) is predicted to be approximately 259.5 bars, and increase to 265.25 bars at the end of the injection period. After the injection period pressure is predicted to rapidly decline, to 261 bars 5 years after the end of injection and 260.25 bars 15 years after the end of injection. At that point pressure decreases asymptotically, approaching the initial pre-injection pressure.

3. Predicted Position of the Carbon Dioxide Plume and Associated Pressure Front at Site Closure

Figure 2 displays the location of the separate-phase carbon dioxide plume (0.05 isoconcentration contour) 15, 40, 75 and 115 years after injection begins, corresponding to the end of injection, and 25, 60 and 100 years after the end of injection. The separate-phase carbon dioxide plume is predicted to move very slowly after the injection period, with a maximum lateral expansion of 2,300 feet from 15 to 115 years (23 feet per year). SJR is submitting a demonstration for an alternative PISC timeframe of 15 years after the end of injection (Section 5). At that point, the leading edge of the separate phase carbon dioxide plume extent is predicted to be located between the 15-Year and 40-Year contour lines on Figure 2.

The pressure front is not plotted on Figure 2 because pressure is predicted to have dissipated sufficiently 15 years after the end of injection below acceptable levels. The pressure front is defined as the threshold overpressure that can be sustained before fluid in the injection zone would flow into a USDW through a hypothetical open conduit as discussed in the AoR and Corrective Action Plan. For example, the threshold overpressure at the injection well location is plotted on Figure 1 for reference, and pressure dissipates below this level approximately 5 years after the end of injection. Similarly, at the injection-zone (IZ) monitoring well location itself, pressure dissipates below the threshold overpressure 6 years after the end of injection (Figure 3).

4. Post-Injection Monitoring Plan

Groundwater quality and plume and pressure-front monitoring activities will continue during the PISC timeframe in a similar fashion as during the injection period, which is discussed in the Testing and Monitoring Plan.

4.1 Groundwater Quality Monitoring

Groundwater quality monitoring will be conducted above the primary confining zone (Freeman Jewett formation) and within USDWs in the vicinity. The Above-Confining Zone (ACZ) monitoring well is located on the SJR property, as shown on Figure 2. The ACZ will be fitted with a continuous pressure gauge in order to monitor increases in pressure that may indicate fluid leakage. In addition, fluid samples will be collected on an annual basis during the post-injection phase for the following per U.S. EPA (2013) protocols:

- Carbon dioxide (ASTM D513 or similar)
- Dissolved metals (EPA 200.8/200.9/7010 or similar)
- Total dissolved solids (ASTM D5907 or similar)
- Major anions (EPA 300.1 or similar)
- Major cations (EPA 6020A/6020C/700B or similar)
- pH, temperature, specific conductivity (calibrated field meter)

Samples will be collected after the well has been purged sufficiently that field parameters (e.g., pH, temperature, specific conductivity) have stabilized. Samples will be collected in bottles provided by a third-party laboratory, and will be submitted under chain-of-custody protocols to the laboratory. Quality assurance/quality control (QA/QC) samples will include one field duplicate, one equipment rinsate/blank, one matrix spike (where needed based on the analytical method) and one trip blank.

As discussed in the Testing and Monitoring Plan, several groundwater production wells located within the AoR are routinely monitored for groundwater level and water quality as a component of compliance with the California Sustainable Groundwater Management Act (SGMA). The AoR coincides with the Southern San Joaquin Municipal Utility District (SSJMUD) Management Area, which is located within the larger Kern County groundwater subbasin (GEI, 2019). Wells are owned by the City of Delano, the City of McFarland, and private parties. All supply wells in the vicinity, including those designated for monitoring, are screened within USDWs overlying the SJR project site. SSJMUD monitors each of these wells for water-quality data (GEI, 2019).

SJR will seek to enter into a memorandum of understanding (MOU) with SSJMUD to (1) gain access to water-quality data obtained from each of the monitoring wells in their network within the AoR; and (2) if needed in order to obtain necessary water-quality parameters, obtain access to the wells for periodic direct sampling.

SJR will seek to collect the following data on an annual basis during the post-injection period (lasting 15 to 50 years – see Section 5 below):

- Carbon dioxide (ASTM D513 or similar)
- Dissolved metals (EPA 200.8/200.9/7010 or similar)
- Total dissolved solids (ASTM D5907 or similar)
- Major anions (EPA 300.1 or similar)
- Major cations (EPA 6020A/6020C/700B or similar)
- pH, temperature, specific conductivity (calibrated field meter)

All data, including original laboratory reports and field notes, will be obtained from SSJMUD if possible. If SJR needs to collect samples independently, samples will be collected after the well has been purged sufficiently that field parameters (e.g., pH, temperature, specific conductivity) have stabilized. Samples will be collected in bottles provided by a third-party laboratory, and will be submitted under chain-of-custody protocols to the laboratory. Quality assurance/quality control (QA/QC) samples will include one field duplicate, one equipment rinsate/blank, one matrix spike (where needed based on the analytical method) and one trip blank.

4.2 Plume and Pressure-Front Tracking

Carbon dioxide plume and pressure-front tracking will continue during the post-injection period with similar methods as during the injection phase, which is discussed in the Testing and Monitoring Plan.

The IZ monitoring well will be installed updip of the project in order to track pressure increases in the vicinity and ensure that pressure increase is similar to model projections. Figure 2 displays the planned location of the Injection-Zone (IZ) monitoring well (35.692503, -119.242309). The IZ monitoring well will be perforated exclusively within the Vedder formation, which is approximately 6,672 ft bgs at this location. Final perforated interval will be determined based on updated stratigraphy obtained during monitoring well drilling. The IZ monitoring well will be fitted with a downhole transducer for continuous pressure measurement.

Figure 3 presents the simulated pressure changes at the IZ monitoring well location during the lifetime of the project based on the project TOUGH numerical model. Pressure measurements at the IZ well and injection well will be compared to corresponding model-simulated pressure profiles to confirm that pressure increases within the Vedder formation are not greater than simulated.

Indirect plume monitoring will include time-lapse three-dimensional surface seismic surveys covering the entire extent of the area anticipated to be subject to carbon dioxide migration. Figure 2 displays the anticipated seismic area overlaid with model simulated extent of carbon dioxide during the lifetime of the project. The anticipated area for seismic surveys is approximately six square miles. The 3D seismic survey will be conducted prior to injection (baseline), at years 2, 5 and 10 during the injection phase, and at years 15 (end of injection) and 30 (15 years after end of injection). Seismic methods will be consistent with U.S. EPA (2013) including ensuring that the exact same methodology is used in repeat surveys.

Surface-seismic results will provide an indication of if supercritical-phase carbon dioxide is present in any given location, but does not generally provide an estimate of carbon dioxide saturation. Plan-view maps of survey results will be compared to model-predicted carbon dioxide extent as shown in Figure 2. All geophysical surveys and reporting will be overseen by a California Registered Professional Geophysicist.

4.3 Schedule and Reporting

All post-injection site care monitoring results will be submitted to U.S. EPA on an annual basis, within 60 days following the anniversary date on which injection ceases. Annual reports will include the following:

- Updated electronic database of all groundwater monitoring results
- Groundwater quality data review as discussed in the Testing and Monitoring Plan
- Comparison of groundwater quality data against baseline (pre-injection) samples for any indication of increasing TDS, changing cation/anion signature, increasing carbon dioxide concentration, decreasing pH, or increasing concentration of dissolved metals
- Original groundwater monitoring laboratory reports
- Calibration records for field meters
- All records from pressure-monitoring, including raw pressure transducer data and plots of pressure over time

- Comparison of model-simulated pressure decline at the IZ-monitoring well location and measured data
- Detailed independent report by the geophysical contractor of all seismic survey methods, map(s) showing all survey equipment positions, date/time of all survey data collection, near surface conditions during the test, raw seismic data and interpreted diagrams, maps showing the location of the carbon dioxide plume, and maps comparing the carbon dioxide plume progression over time to model simulated projections

5. Alternative Post-Injection Site Care Timeframe

An alternative PISC timeframe of 15 years (as compared to the default of 50 years) is appropriate based on the results of the detailed geologic analyses and numerical plume and pressure-front modeling presented in the narrative permit application report and AoR and Corrective Action Plan. In addition to the factors discussed below, a shorter PISC timeframe is supported because the SJR project plans to inject for only 15 years.

This demonstration is based on the following:

Results of Computational Modeling Performed for Delineation of the AoR. AoR delineation modeling, including methods, results, and sensitivity analyses, are presented in the AoR and Corrective Action Plan. These results are used for discussion of plume and pressure front migration below.

Predicted Timeframe for Pressure Decline. Figure 1 displays simulated pressure at the location of the injection well. Initial pressure (prior to injection) is predicted to be approximately 259.5 bars, and increase to 265.25 bars at the end of the injection period. After the injection period pressure is predicted to rapidly decline, to 261 bars 5 years after the end of injection and 260.25 bars 15 years after the end of injection. At that point pressure decreases asymptotically, approaching the initial pre-injection pressure. Similarly, at the injection-zone (IZ) monitoring well location pressure dissipates below the threshold overpressure 6 years after the end of injection (Figure 3).

Predicted Rate of Plume Migration. Figure 2 displays the location of the separate-phase carbon dioxide plume 15, 40, 75 and 115 years after injection begins, corresponding to the end of injection, and 25, 60 and 100 years after the end of injection. The separate-phase carbon dioxide plume is predicted to move very slowly after the injection period, with a maximum lateral expansion of 2,300 feet from 15 to 115 years (23 feet per year). From 15 to 40 years the rate of movement is less than 51 feet per year. At no time during the lifetime of the project or afterwards is the separate-phase carbon dioxide plume predicted to reach sensitive receptors including abandoned wells in the AoR. U.S. EPA (2016) guidance states that when the plume is migrating at a negligible rate as compared to the location of sensitive receptors the plume migration rate may be considered sufficiently minor as to not pose an endangerment to USDWs. The rate of movement predicted for the SJR project and lack of interface with sensitive receptors supports a PISC timeframe of 15 years.

Trapping Processes and Predicted Rate of Carbon Dioxide Trapping. At the SJR site, we predict that trapping occurs primarily by capillary trapping and carbon dioxide dissolution in the brine. Equilibrium geochemical modeling presented in the narrative permit application report indicates minor carbon dioxide mineralization. The AoR and Corrective Action Plan includes a detailed discussion of simulated carbon dioxide fate after injection. Most of the carbon dioxide is trapped as separate-phase carbon dioxide. At the end of injection, about 80% of the total injected mass of 6.57 million tons of carbon dioxide are present in the carbon dioxide-rich gas phase; the remaining 20% are dissolved in brine. After 115 years (100 years after the end of injection), about 64% of the total injected mass of 6.57 million tons of carbon dioxide are present in the carbon dioxide-rich gas phase; the remaining 36% are dissolved in brine.

Confining Zone Characterization. The narrative permit application report includes a detailed evaluation of the Freeman Jewett formation (a Miocene shale and mudstone) which is the confining zone for the project. The Freeman Jewett is approximately 625 feet thick at the injection site. Based on core laboratory analyses the Freeman Jewett formation horizontal permeability is calculated to be 0.26 mD, and vertical permeability is 0.0036 mD. Geochemical modeling indicates that the Freeman-Jewett will not be significantly reactive with carbon dioxide. There are no transmissive faults through the Freeman Jewett at the Site.

Assessment of Potential Conduits for Fluid Movement. The AoR and Corrective Action Plan presents information on abandoned wells within the AoR. There are seven wells within the AoR that penetrate the Freeman Jewett, six of which will require corrective action based on casing and plugging records review. Before the date of site closure all of these wells will have been appropriately plugged and will not be a potential conduit for fluid movement.

Evaluation of the Distance between Injection Zone and Nearest USDW. Delineation of the depth to the top of the injection zone and the depth of the lowermost USDW are discussed in the narrative permit application report. Figure 4 presents the calculated distance between the top of the injection zone and lowermost USDW within the AoR. Distance between the injection zone and the lowermost USDW ranges from 1,774 to 6,907 feet. At the injection-well location the distance is 5,284 feet. This analysis demonstrates that there is significant thickness that exists between the injection zone and lowermost USDW, which as described in the narrative permit application report consists of several fine-grained geologic units. Along with the other analyses described above, the significant thickness between the injection zone and lowermost USDW is another assurance of the limited risk to USDWs and supports a shorter PISC timeframe.

6. Non-Endangerment Demonstration

Prior to achieving Site Closure SJR will submit a demonstration of USDW non-endangerment report to U.S. EPA for approval. The non-endangerment report will include the following (U.S. EPA, 2016):

- Operational and monitoring data: Operational and post-injection phase monitoring data and information, including all relevant testing and monitoring data collected during injection and PISC as listed in the Testing and Monitoring Plan and in the sections above.
- AoR evaluation: Model results, calibrated to all available actual field data (including pressure data, groundwater quality data, and surface seismic results), will be provided in order to support the AoR delineation as revised during PISC.
- Status of potential conduits for fluid movement: All abandoned wells requiring corrective action will be addressed prior to PISC and Site closure. The non-endangerment demonstration will provide all relevant information on abandoned well identification, assessment, and plugging where necessary.
- Evaluation of Reservoir Pressure. Demonstration of pressure decline to levels below those required to mobilize fluids into a USDW will be made based on injection-zone pressure monitoring data, collected as described above. This demonstration will also be supported by the most recent (calibrated) numerical model to support pressure decline demonstrations throughout the AoR.

- Evaluation of Carbon Dioxide Plume. Monitoring data (e.g., surface seismic) and the most recent (calibrated) numerical model will be used to demonstrate that any supercritical plume movement at the time of Site Closure is negligible (e.g., less than 100 feet per year) and poses no danger of intercepting potential conduits for fluid movement. Modeling results will also be used to assess the location of dissolved-phase carbon dioxide, and monitoring results from USDWs and above the confining zone will be used to demonstrate the lack of carbon dioxide leakage over the project lifetime.

7. Site Closure Plan

Site closure activities pursuant to the Class VI permit include notifying the UIC Program Director of the intent to close the Site, plugging all monitoring wells, submitting a site closure report, and recording a notation on the deed to the facility that the land has been used to sequester carbon dioxide (U.S. EPA, 2016).

In practice, the most significant site closure activity will include monitoring well plugging. The recommended plugging and abandonment (P&A) operations described below will squeeze cement into the perforations through a cement retainer. A coiled tubing unit (CTU) will be used to place cement at intervals from plugged back total depth (PBTD) to surface to conform with applicable U.S. EPA standards for a Class VI well.

Plugging procedures will include the following:

Objective: Kill well, remove completion equipment, squeeze perforations with cement.

Summary Procedure:

1. Move in and rig up (MIRU) equipment on location including blowout prevention equipment (BOPE).
2. Run wireline survey to measure bottomhole pressure and confirm PBTD.
3. Kill well with brine of appropriate density to prevent flowback.
4. Pull completion tubing and packers.
5. Land corrosion resistant cement retainer at 7700’.

6. Rig up (RU) cementers. Down squeeze cement through tubing and retainer until pressure increases but remains below formation fracture gradient. Calculate maximum allowable injection pressure based on bottomhole pressure data.

7. Un-sting tubing from retainer and pull out of hole (POOH).

8. RU CTU and place continuous cement plug from top of retainer at 7700′ to surface.

9. Rig down CTU and cementers.

10. Nipple down (ND) BOPE. Rig down move out (RDMO).

11. Dig out cellar, cut casing ten feet below ground level (GL) and flush with outer casings.

12. Weld steel plate on top of casing marked with well API and injection permit number.

13. Survey final well location.

14. 14. Backfill cellar, clean location, and remove all debris. RDMO all equipment and commence applicable surface reclamation efforts.

A site closure report will be submitted to U.S. EPA within 90 days of monitoring well plugging and will include documentation of all plugging activities, location of the sealed injection well and monitoring wells on a copy of the plat survey that has been submitted to the local zoning authority, all required notifications to California and local authorities (and other stakeholders as needed), records of the nature, composition and volume of injected carbon dioxide, map(s) of the AoR and injection and monitoring well locations, site characterization information, and all PISC monitoring records.

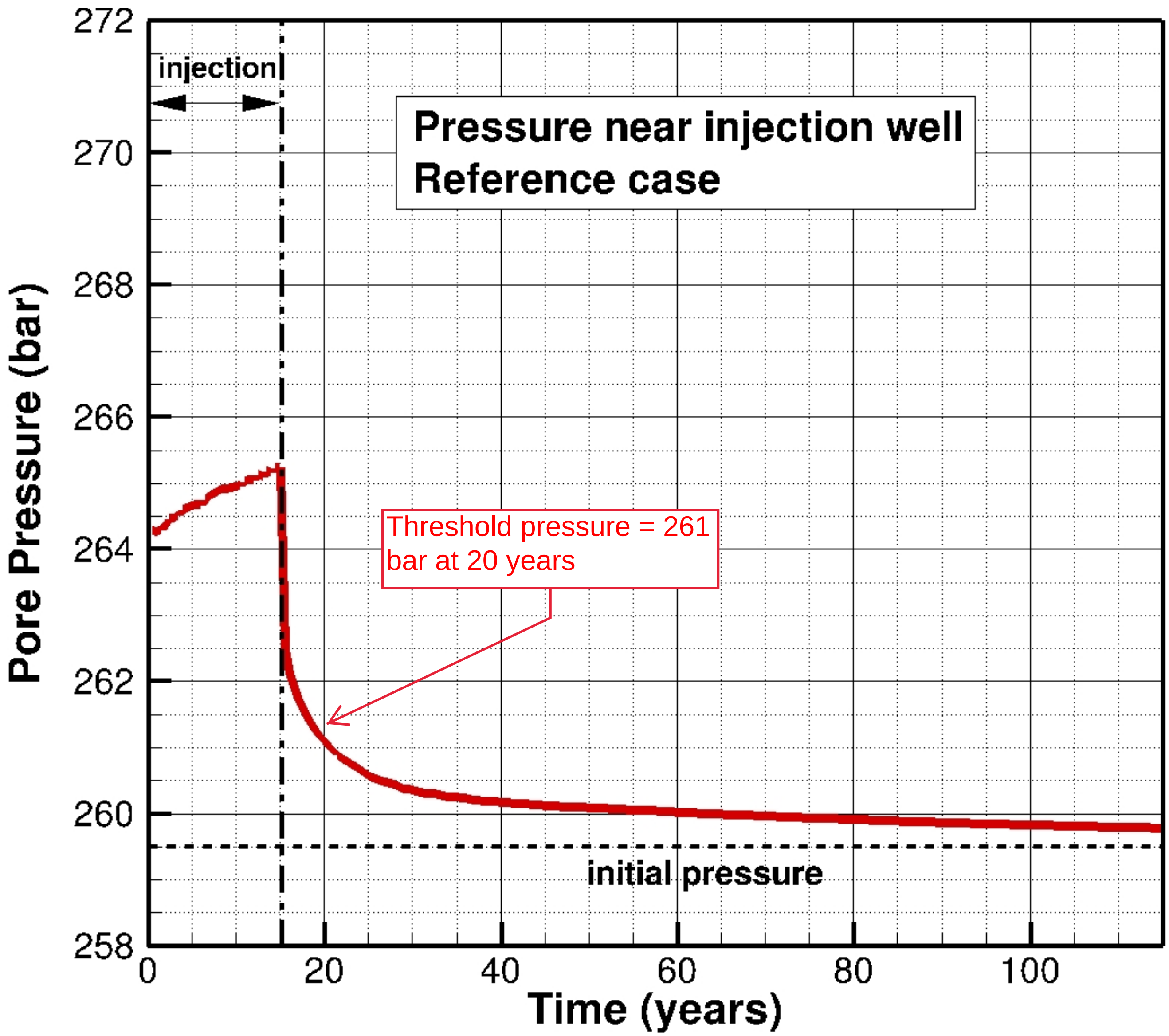
References

GEI Consultants (GEI), 2019. Southern San Joaquin Municipal Utility District Management Area Plan. Submitted to Southern San Joaquin Municipal. December 2019.

United States Environmental Protection Agency (U.S. EPA), 2013. Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance. Office of Water (4606M) EPA 816-R-13-001, March 2013.

United States Environmental Protection Agency (U.S. EPA), 2016. Underground Injection Control (UIC) Program Class VI Well Plugging, Post-Injection Site Care and Site Closure Guidance. Office of Water (4606M) EPA 816-R-16-006, December 2016.

Figures



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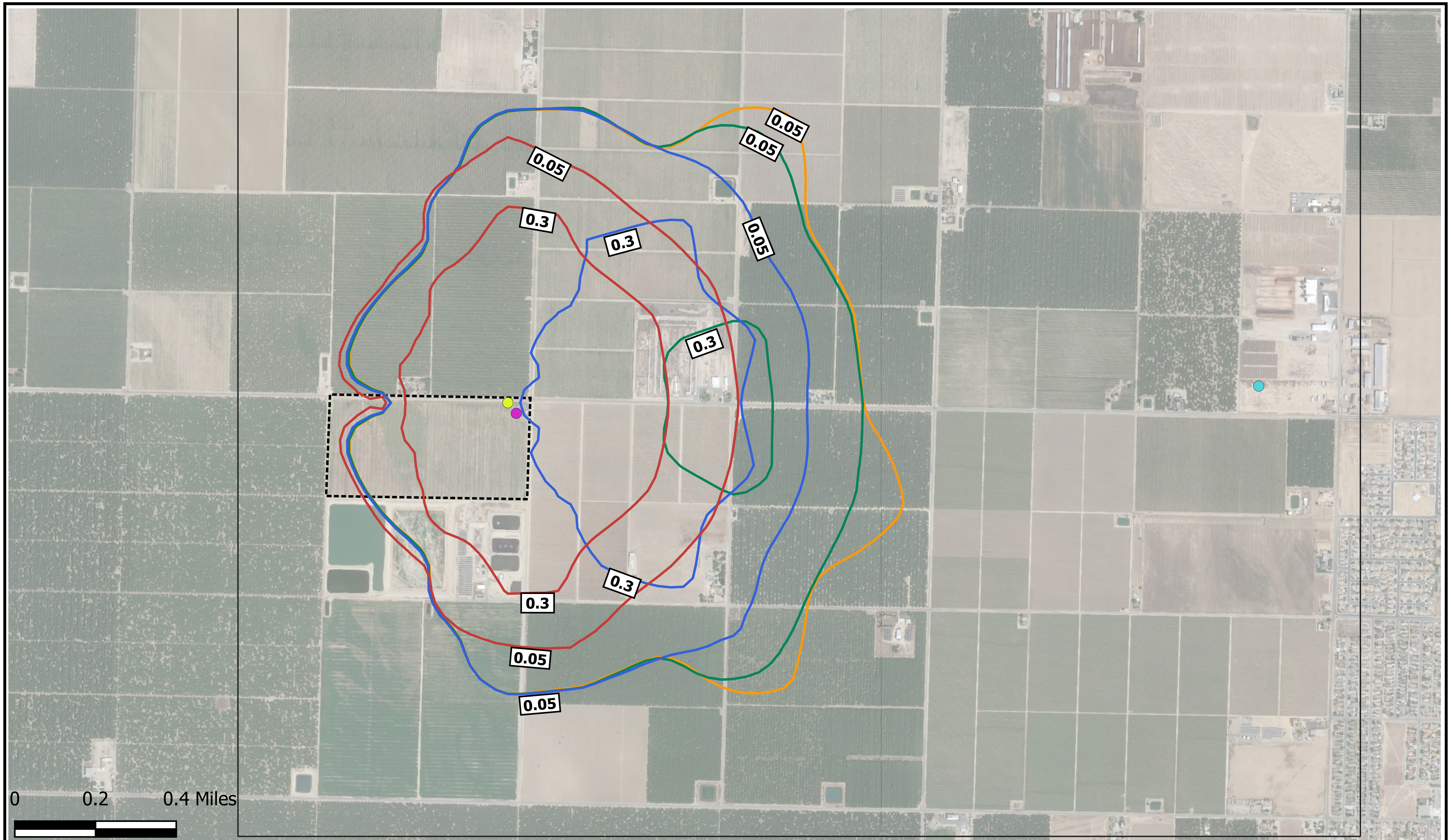
Average Pressure within a 10-m Radius of the Injection Well, Base Case



Explanation

15-Year
40-Year
75-Year
115-Year
Injection Well
Frontline Property Boundary
0.3 Simulated Carbon Dioxide Saturation

Monitoring Wells
Above Confining Zone
Injection Zone
Planned Seismic Area

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Note: Carbon dioxide saturation after the 115-year simulation period is < 0.3

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TOUGH2 simulated maximum carbon dioxide saturation and planned monitoring network

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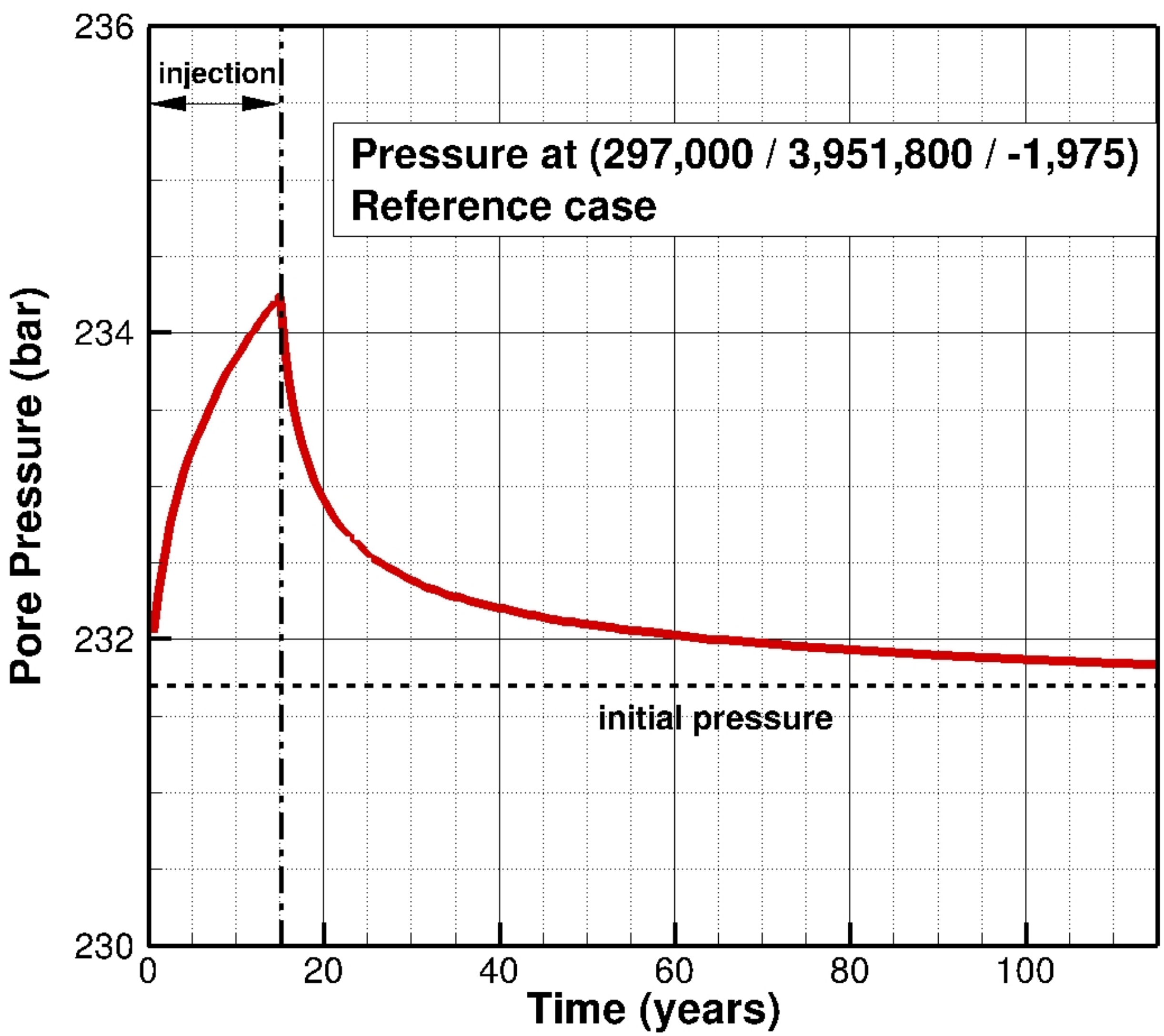
Figure 2



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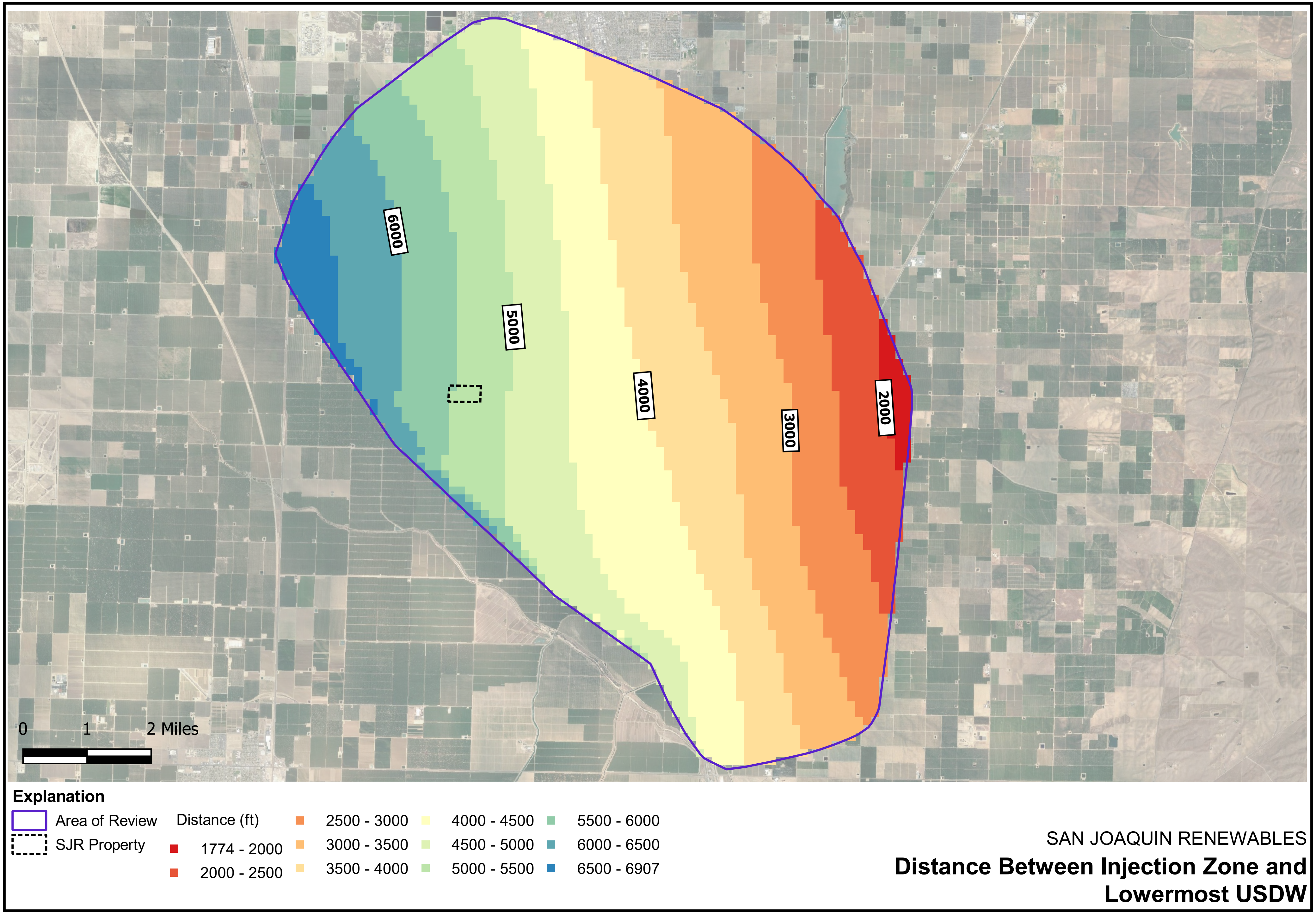
Simulated Pressure Profile at Pressure-Front Tracking Well Location, Vedder Formation



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Distance Between Injection Zone and Lowermost USDW

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Figure 4